



The Benefits of Space Exploration

***Development of an ISECG Paper
...and Related Challenges***

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**NASA Community Workshop on the Global Exploration Roadmap
Applied Physics Laboratory, Laurel, MD
April 11, 2014**



- Senior managers of space agencies participating in the International Space Exploration Coordination Group (ISECG) commissioned development of a collective ISECG paper on the societal benefits of space exploration
- Purpose of the paper:
 - Help agencies communicate more effectively with their respective political decision-makers regarding space exploration benefits
 - Establish common benefits-related framework and vocabulary among agencies
- The ISECG released the paper, "Benefits Stemming from Space Exploration" (Sept 20, 2013)
 - Posted to the ISECG website (www.globalspaceexploration.org)

Issues / Considerations



Past efforts to satisfy stakeholder requirements for reporting of space exploration benefits have had mixed success (e.g. Chase study report for NASA, 1977):

US Comptroller General assessed a study by Chase Econometrics Associates, Inc. to evaluate how NASA R&D spending affects the U.S. economy. The Chase report concluded that this spending produced many benefits between 1960 and 1974, and that "a \$1 billion sustained increase in NASA R&D spending will raise real GNP \$23 billion by 1984." Most of this GNP increase would result from improved technology and productivity, and some would result from increased government spending, "which stimulates spending in different parts of the economy."

However, the Comptroller's assessment concluded that "The Chase study does not prove convincingly that the benefits are as large as stated....Other types of studies are necessary to provide a complete evaluation of NASA R&D. Since similar increases would result from Government spending on other projects, such as welfare programs, the "**multiplier effects**" alone do not justify more NASA R&D spending.... The techniques used had certain shortcomings.... Plausible and seemingly minor changes in the study's assumptions lead to major changes in the results. The results depend upon statistical correlation between NASA R&D spending and changes in a measure of gross productivity in the U.S. economy.... Because of problems in measuring total productivity in the economy and because other possible causes of technological progress were ignored, the correlations may not indicate a true cause-and-effect relationship."

Issues / Considerations (cont'd)



- **Historical context for previous assessments of benefits may no longer apply**
- **Effective quantitative measurement of benefits is very challenging**
- **Different stakeholders value benefit types differently**
 - e.g. Relative value of Tangible vs Intangible benefits
- **To what extent are benefits derived uniquely from space exploration?**

For certain benefits, it is difficult to isolate space exploration's contributions from those of other sources in the aerospace sector or other organizations and entities that also claim roles in delivery of science and technology-related benefits

 - As a result, claims of "space exploration benefits" are open to criticism, either for overpromising, or for underselling.
- **Despite desire by political stakeholders to anticipate benefits in as a pre-condition for space exploration program funding, the serendipitous nature of discovery and innovation makes it impossible to predict the benefits**

No Shortage of Space Agency Benefits Reports



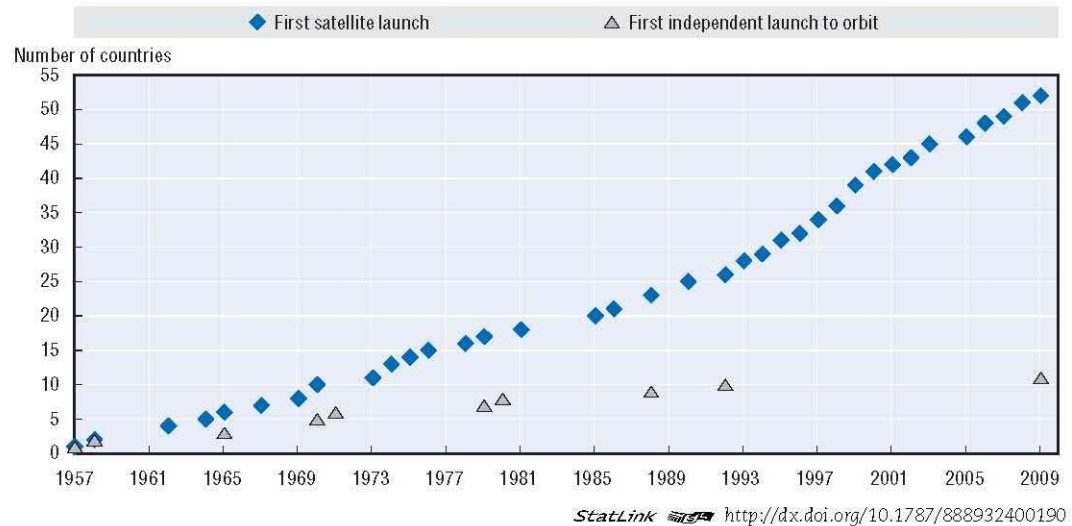
Related Efforts to Measure Benefits: OECD



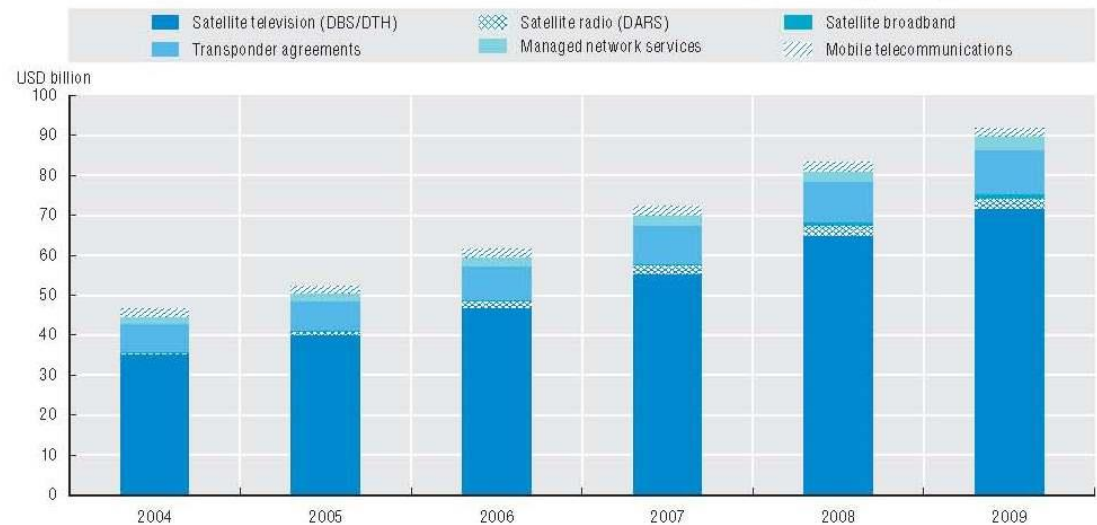
From "The Space Economy at a Glance 2011", OECD

Figure 1.1. **More than 50 countries with spaceflight capabilities in 2010**

Number of countries which launched satellites (independently or via a third party)



5.2 Estimates of satellite communications and broadcasting revenues (2004-09)



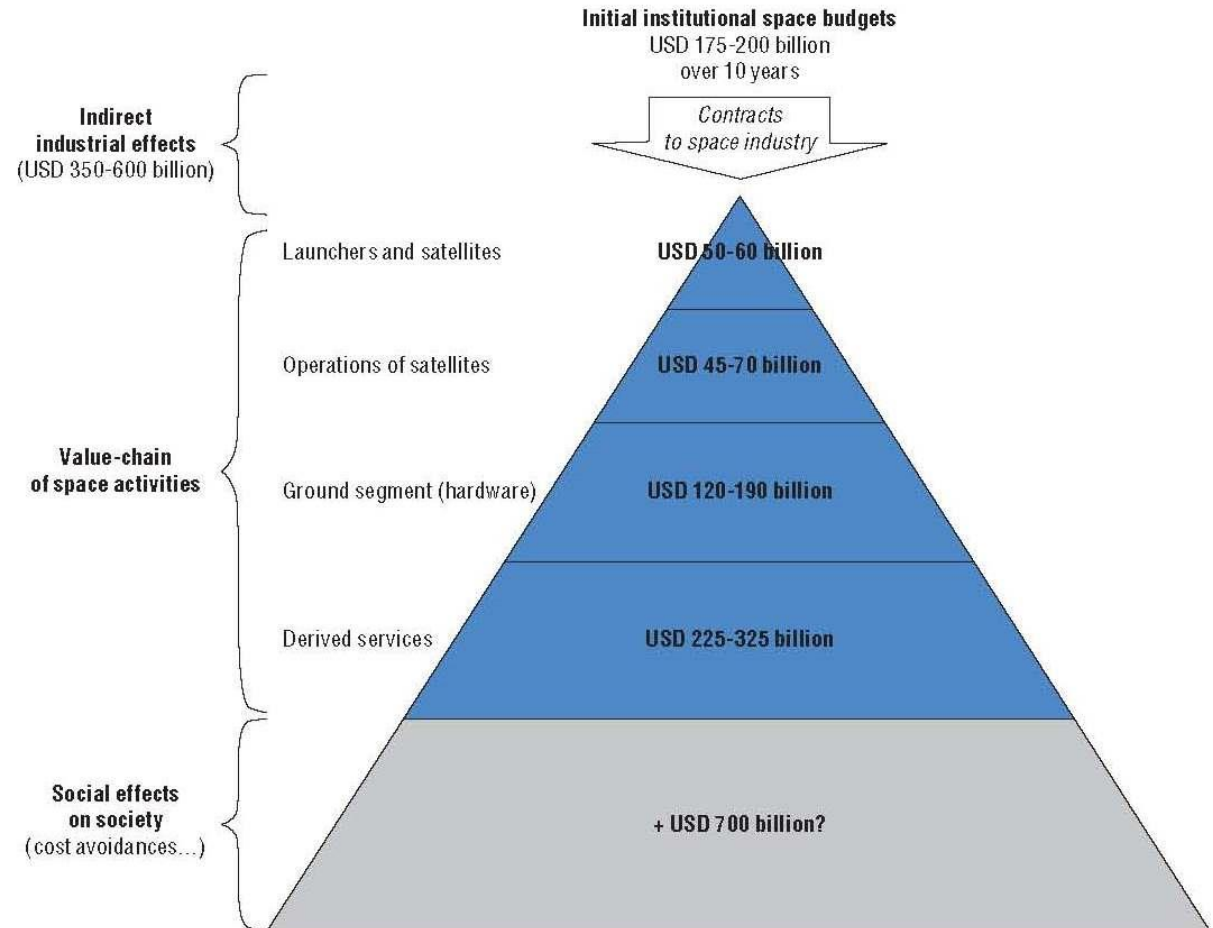
Source: Satellite Industry Association (2010).

OECD: Space Economy at a Glance (cont'd)



From "The Space Economy at a Glance 2011", OECD

Figure 1.6. Estimates on the generation of direct and indirect economic benefits, derived from space activities (1996-2005 period)



Source: Adapted from Cohendet (2010).

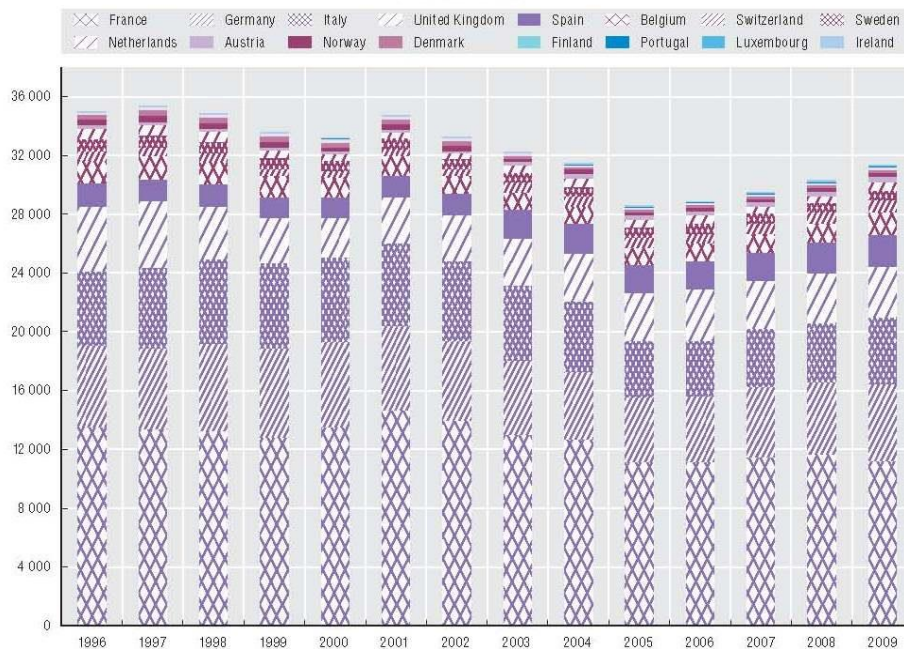
OECD: Space Economy at a Glance (cont'd)



From "The Space Economy at a Glance 2011", OECD

3.1 Employment in space manufacturing in Europe

Full-time equivalent



Source: Eurospace (2010).

StatLink <http://dx.doi.org/10.1787/888932400304>

Box 1.6. List of promising space applications

On the basis of three scenarios, a list of "promising applications" was developed:

Main contenders

- Distance learning and telemedicine (broadcasting to remote areas and across national borders, medical remote surveillance).
- E-commerce (enabling changing work patterns due to mobile workforce/home working and economic consequences, HDTV teleconferencing).
- Entertainment (digital radio, TV, data and multimedia broadcasting to fixed [less likely mobile] assets, high bandwidth to the home/convergence of different media).
- Location-based consumer services (driver assistance and navigation aids, insurance based on real-time usage data, vehicle fleet management, asset tracking (especially high-value) and road repair management).
- Traffic management (location and positioning of aircraft and ships, optimisation of airport traffic management, optimisation of traffic management – road pricing – driver behaviour logging).
- Precision farming and natural resources management (precision agriculture for maximal efficiency in equipment and application of fertiliser, deforestation and forestry management).
- Urban planning (plans, maps and numerical terrain models, precise positioning of engineering structures and buildings, automatic control of job site vehicles, management and optimisation of job site vehicle routes).
- Disaster prevention and management (telecom capability in absence of ground infrastructure, remote assessment of damage and pollution for insurance claims).
- Meteorology and climate change (meteorological and sea condition forecasting for commercial sea shippers, pollution maps with evolution in time, monitoring of the application of treaties, standards and policies).

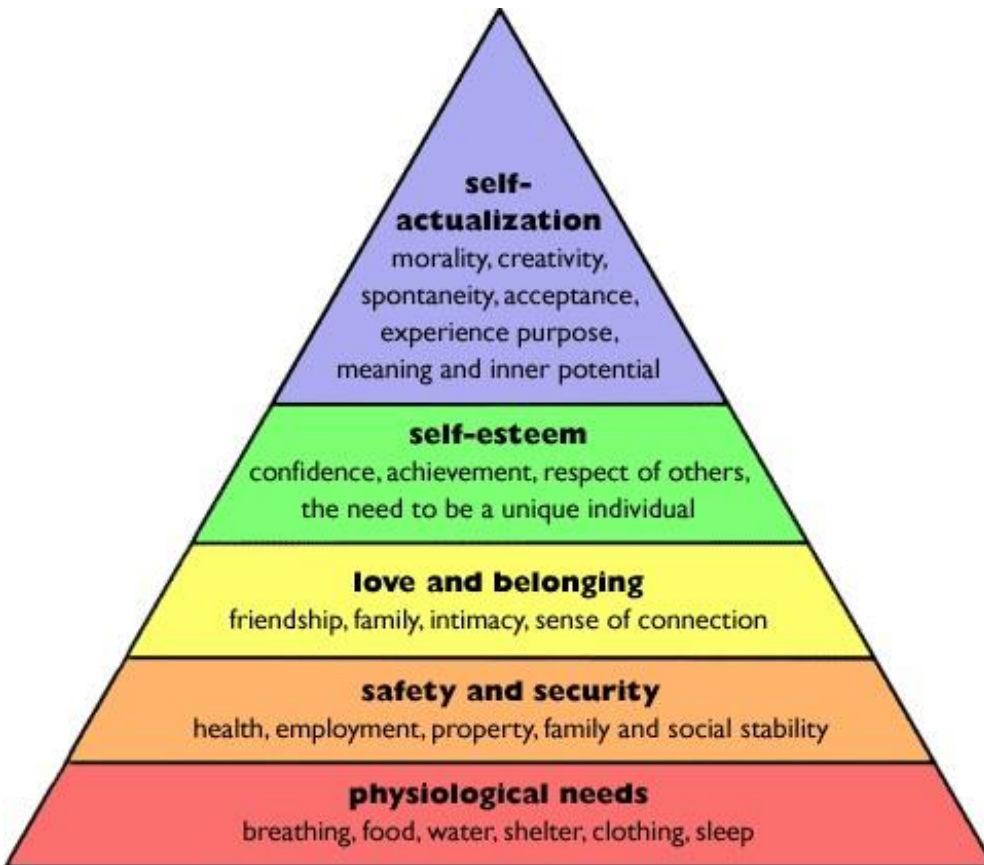
Outsiders

- Adventure space tourism (suborbital then orbital).
- Power relay satellites.
- In-orbit servicing.

A Starting Point: What do people need?



Maslow's Hierarchy of Needs



Max-Neef's Fundamental Human Needs



Classical Texts in Psychology -- A. H. Maslow (1943) A Theory of Human Motivation

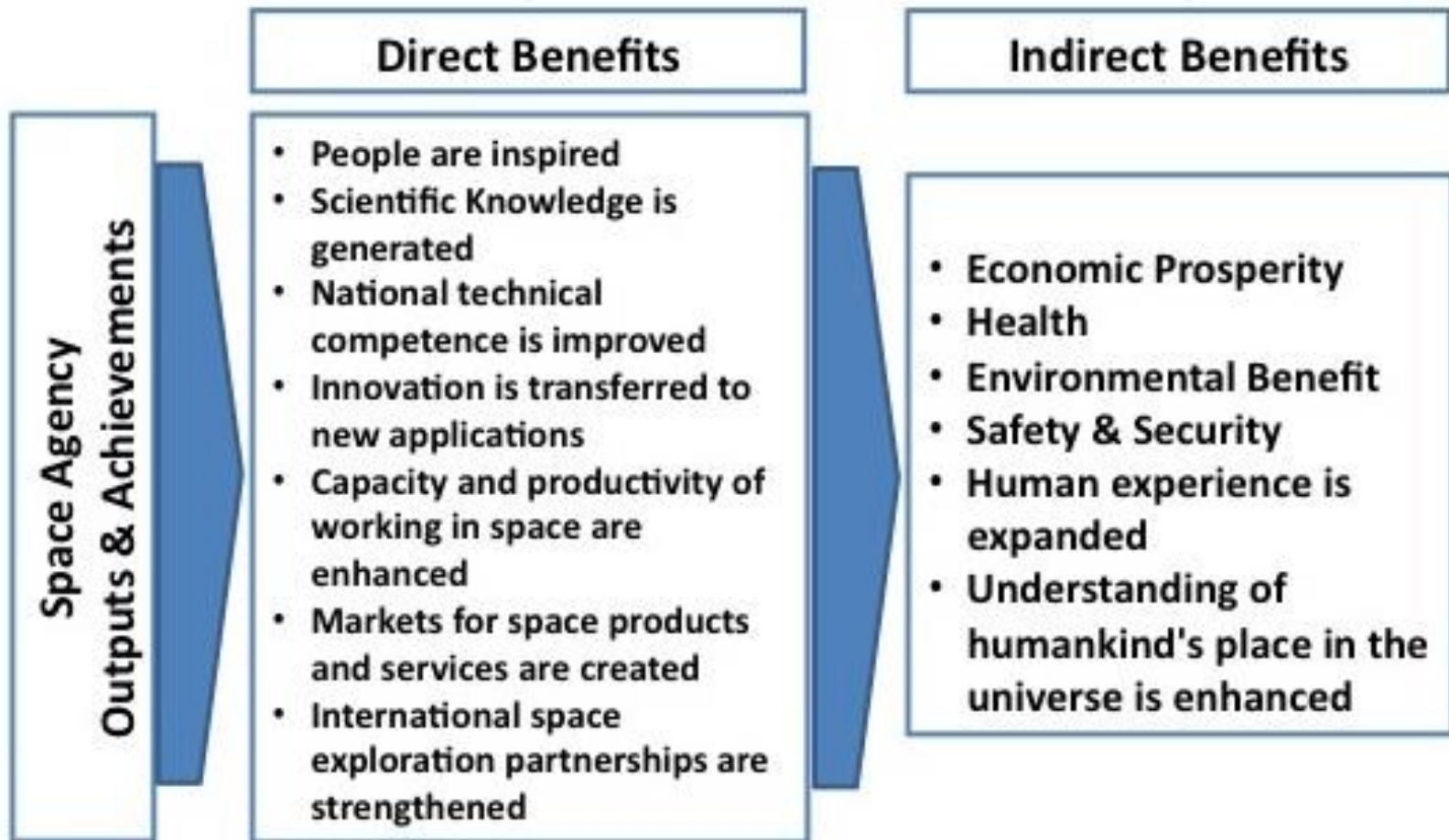
(Return to [Index](#))

A Theory of Human Motivation

A. H. Maslow (1943)

Originally Published in *Psychological Review*, 50, 370-396.

Initial Framework - Value Stream



Executive Summary

1. Introduction

2. Fundamental Benefits of Space Exploration

2.1 Innovation

- Advances in Sci & Tech
- Global Technical Workforce Development
- Enlarged Economic Sphere

2.2 Culture and Inspiration

2.3 New Means to Address Global Challenges

3. Expected Benefits from Exploration Missions in the Next Ten Years

4. Conclusion

Benefits Stemming from
Space Exploration

September 2013



International Space Exploration
Coordination Group

- **Space exploration for 50+ years has produced many societal benefits**
 - Tangible benefits, often unforeseen and serendipitous, began in early years (e.g. Improved computers, solar cells, batteries, fuel cells, etc.)
 - Critical knowledge helped develop space services (e.g. Satellite telecommunications, Global positioning, Weather forecasting)
 - Benefits still delivered today, enhanced by international cooperation (e.g. International Space Station benefits to humanity)
- **Space exploration has the potential to provide a wide range of benefits for humankind in the future**
 - Beyond-LEO exploration documented in the Global Exploration Roadmap requires new capabilities and promises to expand societal benefits
- **The BWP articulates an internationally shared perspective on the nature and significance of the benefits of space exploration, and on the potential for future delivery of benefits**
- **The BWP reflects the strong commitment by space agencies to deliver benefits to society and will help space agencies to engage stakeholders about improving the flow of benefits to society**

The ingenuity required for space exploration is harnessed to generate benefits for humanity

Advances in Science & Technology

- Benefits across a broad spectrum of societal priorities such as health & medicine, transportation, environment, and public safety

Global Technical Workforce Development

- Space exploration is a key motivation to pursue careers in science, technology, engineering, and mathematics (STEM)
- Studies have demonstrated the link between space exploration and inspiration to study STEM fields

Enlarged Economic Sphere

- Investment in space is becoming attractive to private entrepreneurs
- Examples include the first resupply mission to the International Space Station (ISS) and the development of space habitation systems



Innovation Example: neuroArm



Canadian Space Agency

Canada

Audiences Activities Sectors Resources Useful Links Multimedia

Home Activities Sectors ISS International Space Station Benefits for Humanity

General Information

Can I see the Space Station from my back yard?

How big is the ISS?

Modules of the Station

News

Canadian Science

The Payload Telescience Operations Centre

Current Experiments

Past Experiments

Robotics

Canadarm2

Dextre

Mobile Base System

Robotic Refueling Mission

Operations Complex

Canadian Flight Controllers

History: The Space Shuttle's Canadarm

Benefits: neuroArm

International Space Station Benefits for Humanity

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neuroArm: Robotic arms lend a healing touch



"Where the robot entered my head," says 21-year old Paige Nickason, the first patient to have brain surgery performed by a robot as she points to an area on her forehead. "Now that neuroArm has removed the tumor from my brain, it will go on to help many other people like me around the world."

By: The Canadian Space Agency

The delicate touch that successfully removed an egg-shaped tumor from Paige Nickason's brain got a helping hand from a world-renowned arm—a robotic arm, that is. The technology that went into developing neuroArm, the world's first robot capable of performing surgery inside magnetic resonance machines, was born from the Canadarm (developed by MDA for the US Space Shuttle

NEUROARM

HOME NEWS PROJECT PEOPLE IMAGES SOFTWARE LINKS PUBLICATIONS

NEUROARM

The Future of Neurosurgery.

Introducing an MRI-compatible image-guided computer-assisted device specifically designed for neurosurgery.

Overpromising or Underselling? Space Exploration and Cancer Research



National Aeronautics and Space Administration



NASA Contributions to Cancer Research



Since its founding fifty years ago in 1958, NASA's exploration and research missions have benefited people around the world through the expansion of our civilization's horizons, the acquisition of knowledge, and the development of new technologies and applications that provide amazing new advances in the quality of human life. What follows is a brief overview of how technologies developed through the Nation's investment in aerospace research have come back down to Earth to benefit the medical community in its understanding of cancers and cancer treatments.



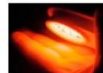
NASA is partnered with the National Institutes of Health (NIH) to use the U.S. portion of the Space Station for medical research, including cancer studies.

[/www.niams.nih.gov/News_and_Events/NIH_NASA_Activities/nih_nasa_mou.asp](http://www.niams.nih.gov/News_and_Events/NIH_NASA_Activities/nih_nasa_mou.asp)



To simulate the weightless conditions of space and thereby bring the advantages of ISS research to laboratories on Earth, NASA developed a bioreactor device to simulate the effect of reduced gravity.

science.nasa.gov/NEWHOME/br/bioreactor.htm



LED Photodynamic therapy research has been applied to activating cancer drugs once they have been pinpointed inside a tumor.

ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20060022057_2006145857.pdf



Charge-coupled devices (CCDs) used in the Hubble Space Telescope to convert a distant star's light into digital images have been adapted to improve detection of small masses in breast tissue.

ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20020080116_2002131836.pdf



Another technique for analysis of mammography uses software designed by NASA to significantly improve the extraction of patterns from complex data sets, like those returned from deep space.

ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20080003922_2008001499.pdf



The potential of carbon nanotubes to diagnose and treat brain tumors is being explored through a partnership between NASA's Jet Propulsion Laboratory, and City of Hope, a leading cancer research and treatment center in California.

www.jpl.nasa.gov/news/news.cfm?release=2008-006



The BioScan System, developed by OmniCorder Technologies, Inc. at NASA's Jet Propulsion Laboratory, is able to locate cancerous lesions by detecting the cancer's ability to recruit a new blood supply. This technology will reduce the time taken to detect cancerous cells and allow for earlier intervention.

www.sti.nasa.gov/tto/spinoff2000/hm3.htm

Find out more at NASA's Innovative Partnership program website
<http://www.ipp.nasa.gov/contributions.htm>

Space Exploration's impact on education/career choices

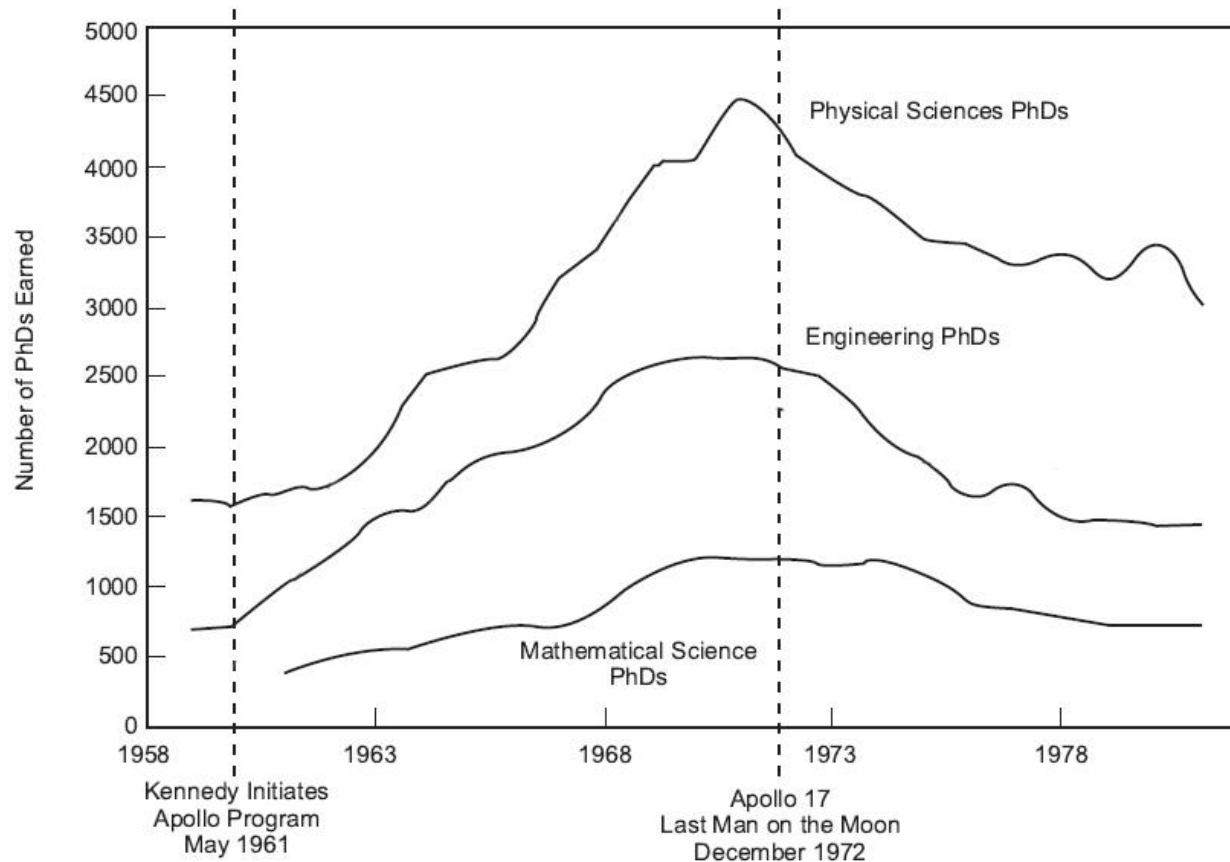


NATURE/APOLLO SURVEY 2009

APOLLO SURVEY RESULTS

Did the Apollo missions inspire you in any way to become a scientist?

Yes, strongly	18.0%
Yes, somewhat	32.0%
Not at all	42.3%
I was already a scientist or on track to become one	7.7%



Culture and Inspiration



Space exploration provides a unique perspective on humanity's place in the universe

- **Exploration fulfills human curiosity and inspires wonder**

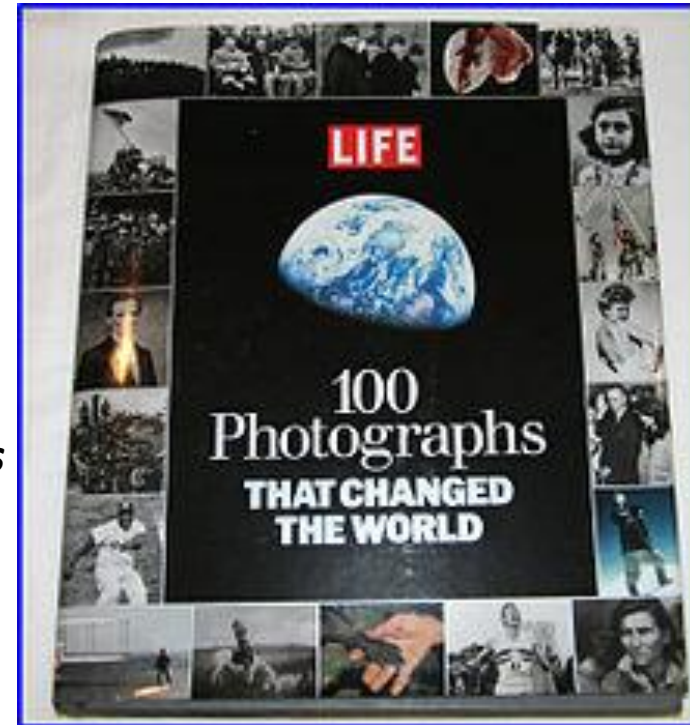
Enduring questions:

- What is the nature of the Universe?
- Is the destiny of humankind bound to Earth?
- Are we and our planet unique?
- Is there life elsewhere in the Universe?

- **Giant leaps for humankind**

Exploration missions expand our views about the limits of human travel and the possibilities for humanity

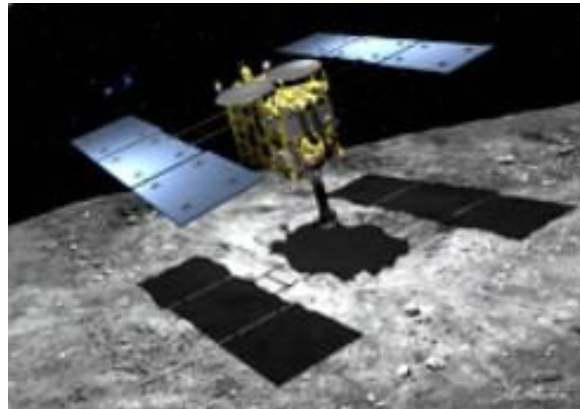
- **Evidence of past or present life in the solar system would affect humanity's appreciation of life's uniqueness on Earth**



Space Exploration's Impact on Culture & Inspiration



An example from Japan: Multiple feature films about the Hayabusa mission were produced



New Means to Address Global Challenges



Space exploration is a catalyst for nations to build mutual understanding and trust

Space exploration creates opportunities to produce unique solutions for dealing with global challenges including hazardous Near Earth Asteroids; Solar storms; Space debris; Environmentally sustainable development

- **International Partnerships**

- Mutual understanding, trust
- Including developed and developing countries



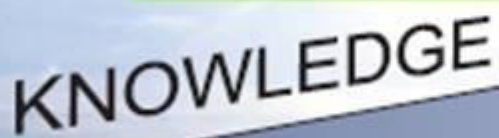
- **Advancing Capabilities for Global Protection**

- Space-based systems can provide direct benefit to people on Earth



Evolving exploration generates societal benefits

Evolving exploration generates societal benefits



TODAY

Exploration

1957

57 Human and Robotic Space Exploration



INNOVATION

CULTURE & INSPIRATION

ADDRESSING GLOBAL CHALLENGES





NASA's 2014 Strategic Plan and the Socio-Economic Impact of NASA

March 2014



The International Space Station

Expand the frontiers of knowledge, capability, and opportunity in space

- 200** People who have visited the ISS by the end of 2013
- 1,500** Scientific investigations performed aboard the ISS from 1998 to 2013
- 1,400** Peer-reviewed published papers featuring research conducted on ISS from 1998 to 2013
- 42M** Students reached through ISS educational events from 1998 to 2013
- \$1.5B** Estimated future commercial revenue from Falcon 9 and Antares launches booked by private sector (as of Feb 2014)



ISS research has contributed to advances in health, environmental sciences, education, and has helped revitalize the U.S. launch industry

6

NASA Collaboration

Expand the frontiers of knowledge, capability, and opportunity in space

- 5,000** Participants across 117 teams in NASA Challenges work to solve some of the Agency's toughest problems
- 1.2M+** People from over 80 countries participating in NASA citizen scientist projects
- 7,000** Businesses and other organizations that had contracts with NASA in 2013
- 1,300** Research projects funded in 2013
- 500** Companies collaborate with NASA to perform work documented in Space Act Agreements
- 100+** Agreements with international entities from 28 countries were signed in 2013



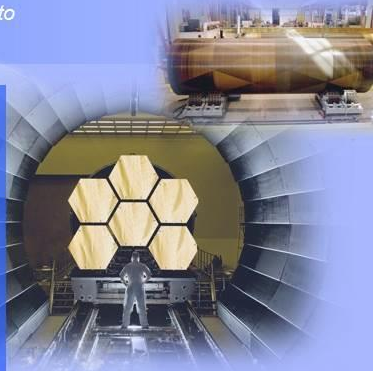
NASA works with U.S. industry, academia, and international partners to expand the frontiers of knowledge, capability, and opportunity in space

7

Knowledge Transfer

Advance understanding of Earth and develop technologies to improve the quality of life on our home planet

- 1,600** Potential new inventions generated by NASA civil servants and contractors in FY 2013
- 2,150** Number of new domestic partnerships or technology transfer agreements, which includes Space Act Agreements and Software Usage Agreements and Licenses in FY 2013
- 1,000** Number of agreements with federal, state, and local governments
- 500** Number of companies NASA collaborates with using Space Act Agreements
- 1,800** Documented spinoffs from NASA technologies that have been commercialized, ranging from innovative manufacturing techniques to new materials
- >1B** Estimated number of cell phones sold each year since 2010 using NASA-developed imaging semiconductors
- 500 yrs** Length of time a semiconductor can last based on NASA-developed manufacturing techniques



NASA transfers its knowledge, products, services and processes to spur innovation in U.S. industry and help American businesses grow.

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NASA's 2014 Strategic Plan and the Socio-Economic Impact of NASA

March 2014



Education and Outreach

Serve the American public and accomplish our Mission by effectively managing our people, technical capabilities, and infrastructure

1B Number of visits and downloads of NASA datasets in 2012

60M Number of views of NASA educational websites each year

12M Number of Twitter followers, more than any other government agency

1.5M Number of NASA mentions in English language academic articles during the previous decade

9,000+ Number of students who applied for NASA internships in FY 2013

1,200+ Number of NASA internships awarded to in FY 2013

50% Percentage of world renowned scientists who cite Apollo as a major reason they pursued a science career



In 2012, the Curiosity rover landing on Mars was viewed 3.2 million times

NASA has won multiple Shorty Awards for best government use of social media and emphasis on getting children interested in space



16

NASA's Annual Socio-economic Impacts

Expand the frontiers of knowledge, capability, and opportunity in space

10,000
Papers based on Hubble Space Telescope data published

1,300
Research projects funded by NASA

7,000
contracts between NASA and businesses

NASA has contracts with companies in all 50 states

1,000
Requests by U.S. industry for human spaceflight technologies

\$1.5B
Estimated value of private sector bookings for Falcon 9 and Antares launches

200 people have visited the ISS
1,500 investigations conducted on ISS

Advance understanding of Earth and develop technologies to improve the quality of life on our home planet

636 million
EOSDIS imagery data downloads

3 million
Landsat scenes downloaded

4 billion gallons
Jet fuel saved due to use of NASA-developed winglets on aircraft

\$1,700
Amount saved per flight due to use of NASA-developed air traffic control technologies

90%
Percentage of baby food that has a nutritional supplement identified via NASA research

30,000
Lives saved from using NASA-developed satellite tracking systems

Serve the American public and accomplish our Mission by effectively managing our people, technical capabilities, and infrastructure

1,600+ new technology inventions in FY 2013

Software usage agreements in FY 2013

Patent and copyright licenses in FY 2013

Space Act Agreements and SBIR/STTR contracts in FY 2013

2,150+ domestic technology transfers

Visits and downloads of NASA datasets in 2012

12M Twitter followers (NASA programs, people, and centers)

60M Views of educational websites per year



- **Over the years, space exploration has produced an impressive record of benefits for humanity**
- **There is no activity on Earth that matches the unique challenges of space exploration.**
- **The first fifty years of space activity have generated benefits for people around the globe. This past record gives strong reason for confidence that renewed investments in space exploration will have similarly positive impacts for future generations**